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Title: What Actually Is Meant by "Proliferation Resistance" in Discussions of Advanced Nuclear Fuel Cycles?

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What Actually Is Meant by "Proliferation Resistance" in Discussions of Advanced Nuclear Fuel Cycles?

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Abstract

The term "proliferation resistance" is used to denote many different things in the context of nuclear fuel cycles. This range of meanings commonly leads to miscommunication between and within the nuclear fuel cycle and safeguards communities. With the hope of adding clarity to the dialogues, this paper describes some of the definitions that have been and are used (explicitly and implicitly) for "proliferation resistance." The focus is restricted to fuel cycles involving separations with particular emphasis on the Advanced Fuel Cycle Initiative, and some common fuel cycle paradigms are used to illustrate why imprecise definitions needlessly confuse communication. The evaluation also is limited to international safeguards, where the threat is posed by the State owning the facilities rather than a sub-national group. The authors conclude by urging users of the term "proliferation resistance" to be explicit in defining the threat scenario(s) to which the term is being applied.

Introduction

It is commonly accepted that one of the requirements for achieving a renaissance in the American nuclear power industry is making the technology "proliferation resistant". Unfortunately, there is no consensus as to what proliferation resistance (PR) actually is. Indeed, the literature is full of examples of technologies that are said to confer or enhance PR without any attempt at a definition. Further, many definitions that are in use ignore important aspects of PR.

This paper will examine some of the aspects that must be captured in an acceptable definition of PR, examine some recent definitions, and then propose a straw man definition for further discussion by the various communities with a stake in the issue.

Why Should We Care How PR Is Defined?

The position can be advanced that having an agreed upon definition of PR is not really necessary since everyone has an intuitive idea of what is meant. However, this sort of approach is fraught with perils. As noted above, proliferation concerns along with safety and economics are a major barrier to restarting the nuclear power industry in the United States. When it is asserted that this or that technology solves the proliferation problem, the claim will have to stand up to careful scrutiny by both the friends and enemies of nuclear power. If it can be shown that results being claimed are not effective against the threat, it will condemn nuclear technology to the same loss of credibility that occurred in the 1970s after Three Mile Island. Therefore, it behooves the friends of nuclear power to be very careful in what they say they are accomplishing.

Also of concern is the chance that considerable resources can be expended in the development and implementation of technologies that only solve a small part of the problem while possibly exacerbating other areas of proliferation prevention. A measure that slows access by a violent outsider to nuclear material may significantly degrade materials accounting sufficiently to hamper detection of material loss to a non-violent insider.

As experts in the technology of managing nuclear material, we have responsibility to give the best possible advice to decision makers. Precise use of language is an important aspect in such dealings.

What Should Be in a Good Definition?
There are several features, the authors believe, that must be captured in a good definition of PR.

Threat
There are two possible threats that are referred to in the PR literature. The first is the sub-national or terrorist threat. These groups seek to steal material from a facility against the will of the facility owner/operator. This would include state-supported terrorist groups.

The second threat is the national one. That is the threat that a facility owner/operator will divert nuclear material from his own facility so that the State where the facility is located can build a nuclear weapon contrary to its treaty or other obligations.

It should also be noted that the time frame of the threat is important. A measure that provides a few hours delay of a violent outsider may be very important in that situation. However, it is unlikely to have a significant impact on a threat measured in years or centuries.

As Table 1 demonstrates, the efficacy of a PR measure is dependent on the threat. In the table, three commonly suggested PR measures are evaluated for their effectiveness in resisting removal by sub-national or national proliferants.

Table 1. Effectiveness of Selected Different PR Measures Against Different Short-Term Threats

	National	**Sub-National**
Difficult to separate chemical form	Ineffective	Effective
Radiation barrier	Ineffective	Effective
High-Burnup Pu	Ineffective	Somewhat Effective

Modalities of Resistance
There are two modalities that can be used to resist proliferation. These are called intrinsic and extrinsic.[1] Intrinsic means are those that are inherent in a technology and make diversion and/or use of nuclear material more difficult. Examples put forward include, *inter alia,* those shown in Table 1. These have the effect of requiring more resources before the proliferator can obtain nuclear material for a nuclear weapon. The second modality is called extrinsic. This includes active, institutional measures such as safeguards that complicate the diversion of nuclear material.

PR Is a Continuous Not a State Function
There is no state of a facility or technology that can be called proliferation resistant. Rather, facilities and technologies are more or less proliferation resistant relative to other technologies. This can be stated either qualitatively or quantitatively. A technology such as the Integral Fast Reactor may be more or less proliferation resistant relative to the current once-through technology based on light water reactors.

Alternatively, PR may be stated in terms of an absolute engineering parameter, such as the length of time a proliferant may require to separate Pu from a molten salt solution. The value of a given technology may have to be stated in terms of a number of different engineering parameters such a cost, dose rate, limit of error, and detection limit.

Use and Operational Definition
An operational definition is one that tells someone how to measure the quantity in question. A somewhat facetious example might be, "If it walks like a duck and quacks like a duck, it is a duck." This concept was developed by the Nobel laureate in physics, P. W. Bridgeman, as a way of more exactly specifying scientific concepts.[2]

Examples
Two recent definitions of PR are discussed here.

> **Proliferation Resistance is defined as that characteristic of a nuclear energy system that impedes diversion of undeclared production of nuclear material, or misuse of technology, by States intent on acquiring nuclear weapons or other nuclear explosive devices**
> - **The degree of proliferation resistance results from a combination of ...*intrinsic* and *extrinsic measures*.**
>
> "Guidance for the Evaluation of Innovative Nuclear Reactors and Fuel Cycles"[3]

This definition has some good characteristics. It includes the threat that is being considered (diversion by a State), recognizes intrinsic and extrinsic measures, and acknowledges that PR is a matter of degree, not a state. However, there is no indication of how to measure PR.

> **The term conceptualizes the characteristics that are deterrents to theft, diversion, and retrieval of fissile material for use in weapons. Its characteristics relate to the form of the material (chemical and physical), its location (a measure of the degree of accessibility), and applied safeguards and security provisions (which depend on institutional controls.)**
>
> "Technical Summary Report for Weapons Usable Plutonium Disposition"[4]

The threat here is not explicit in the definition. However, there is a suggestion of which modalities are being considered, and how to measure PR.

Toward a Common Definition
The authors recognize that arriving at a universal definition will require extensive interaction among the members of the nonproliferation community. Therefore, the definition given below should be considered a "straw man" for discussion.

However, there is a need for choices in two areas that we believe need to be made in addition to the features outlined above. The first area is part of the threat definition. As we have said, the effectiveness of a PR measure is dependent on the threat. We believe that both national and sub-national threats need to be addressed in discussions of PR. As seen above, the time frame of threat is also important. Unmodified use of the PR should therefore be assumed to refer to all time periods. To be any less specific would open the nuclear community to charges of dodging important issues. The other area we are concerned with is the commitment to considering both intrinsic and extrinsic PR in any system. It should be obvious that no facility will be built that is based solely on intrinsic PR. Thus, there must be recognition up front that extrinsic measures will be applied, and that there may be both positive and negative interactions between these two modalities.[5]

With these things said, the following straw man definition is proposed:

<u>Proliferation Resistance</u> is a measure of the effect one or more intrinsic or extrinsic features of a technology have on the availability of nuclear material to sub-national or national groups over any time period. The magnitude may be expressed:

- **Qualitatively (relative to another technology)**

  OR
- **Quantitatively (i.e., delay time, dose rate, cost, limit of error, detection limit).**

The definition given here is very inclusive. This definition meets the criteria discussed above and adds a precision to the discussion of proliferation resistance that has been lacking in previous discussion.

References

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